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Adoption and utilisation of Zai pits for improved farm productivity in drier upper Eastern Kenya

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Abstract

Inadequate and poorly distributed rainfall and declining soil fertility have led to low crop productivity in most smallholder farms in sub-Saharan Africa. As a result, there has been a renewed quest for sustainable and resource-use efficient agricultural production practices. Zai pit technology is a practice that has the potential to alleviate water stress and enhance soil fertility. We assessed the factors that influence farmers' adoption and utilisation of Zai pits in Tharaka-Nithi County in upper Eastern Kenya. We interviewed 291 farm household heads. Descriptive statistical analysis and a logistic regression model were applied to evaluate socio-economic factors that affect the adoption of Zai pits by farmers. Binary logistic regression estimation revealed that the number of non-formal training, beneficiaries of nongovernmental organisations, wealth status and membership of a social group play an essential role in the adoption of Zai pits. Based on the findings, we recommend that farm characteristics and socio-economic characteristics of farmers should be considered in the promotion of Zai pits as a water harvesting technology. The results of the study will be useful to extension service providers in planning, designing and evaluating effective and efficient agricultural policies, programs and projects at local, regional and national scales in the dissemination of Zai pit technology among smallholder farmers in the semi-arid tropics.

Keywords: Erratic rainfall, non-government extension agents, socio-economic, water harvesting

1 Introduction

Low rainfall, soil moisture stress and low nutrient availability have been major constraints that impinge crop productivity in arid and semiarid environments of the world (Yazar & Ali, 2016). Moreover, frequent occurrences of droughts and dry spells experienced in rainfed agriculture in Africa (Ayanlade *et al.*, 2018) threaten food security (Grafton *et al.*, 2015). In 2008–2010 drought in the Horn of Africa affected more than 13 million people, including 3.75 million Kenyans (Muller, 2014). According to the Intergovernmental Panel on Climate Change [IPCC] (2014) and Muller (2014), African rain-fed agriculture will severely be affected by the ongoing climate change and variability (Mukherjee *et al.*, 2018). In developing countries, rainfed grain yields average 1.5 $t\,ha^{-1}$ (Rosegrant *et al.*, 2002) compared with 5-6 $t\,ha^{-1}$ (Rockström & Falkenmark, 2000) in regions with reliable rainfall and sufficient nutrient availability (Clarke *et al.*, 2017). The yield gap between the actual yields being harvested from farmers' fields and what could be potentially realised attests the need to develop new approaches of agricultural production in sub-Saharan Africa (Wani *et al.*, 2009). A 8-22 % yield loss is estimated for the main grain crops such as millet, sorghum and maize by 2050 unless sustainable techniques are adapted to mitigate the effects of rainfall anomalies and soil fertility decline (Schlenker & Lobell, 2010). These observations suggest that to overcome the biophysical constraints and intensify yield production in rainfed farming systems in tropical developing countries, soil water conservation in combination with nutri-

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ent management should be recommended (McLellan *et al*., 2015; Zougmoré *et al*., 2014). Integrating water harvesting technologies with soil fertility management techniques can create synergies that can further increase water use efficiency and hence, higher yields (Jägermeyr *et al*., 2016). Use of climate adaptation strategies that combine water and soil management (Partey *et al*., 2018) such as Zai pit increase rainfall use efficiency and bridge intraseasonal dry spells increasing agricultural productivity (Dile *et al*., 2013; Wildemeersch *et al*., 2015).

A 'Zai' is a hole dug into the soil but of different sizes depending on farmer innovation. Zai pits are technologies initially practised in Burkina Faso, although some literature points it to Dogon in Mali (Danjuma & Mohammed, 2015; Partey *et al*. 2018). Zai pit also called Tassa in Niger (Partey *et al*., 2018), is an intervention that improves precipitation capture, reduces runoff and evaporation, and increases agricultural productivity (Wouterse, 2017). Since crusted soils characterise most cultivated lands by hardpan formation, compaction, inadequate aeration, reduced permeability and limited plant root development (Zougmoré *et al*., 2014), Zai pit can enhance more water infiltration and increase runoff collection (Amede *et al*., 2011; Kaboré & Reij, 2004). Zai pit system has been promoted by non-governmental organisations (NGOs) and other international organisations in many developing countries like Niger, Zambia, Ethiopia South Africa among others (Fatondji *et al*., 2009; Gumbo *et al*., 2012; Haggblade & Tembo, 2003; Thierfelder & Wall, 2009).

In Kenya, most farmers know Zai as the 'five by nine' pit or Tumbukiza whose metric dimensions are 60 cm wide by 60 cm long by 60 cm deep (Kathuli & Itabari, 2015 ; Biazin *et al*., 2012). These pits are slightly bigger than the conventional Zai, which are considered to be 20-20 cm in diameter and 10-15 cm deep (Bandre & Batta, 2002). The 'five by nine' refers to the five or nine maize seeds (for dry areas or wet areas respectively) planted at the pit diagonals (Mati, 2005). This type of pit can be re-used for up to 3 years (Mati, 2005). A farmer can dig between 4,000 to 6,000 Zai per hectare depending on the spacing. Mostly, pits are spaced 0.6-0.8 m and dug in alternate rows to increase the capture of eroded soil and reduce runoff water (Sidibe, 2005). In each Zai, the farmer adds a mixture of crop residue, farmyard manure and topsoil and then places either the seed to be planted or an entire plant, depending on the type of propagation material. Zai pit technology has been used in production of staple food crops such as sorghum, millet, maize. pigeon peas and lablab (black beans) among other drought resistant crops in the semi-arid areas.

Factors influencing the adoption of Zai pits could be regional or household-specific due to variations in socio-cultural, economic and biophysical conditions (Amsalu & de Graaff, 2007). In northern Burkina Faso, farmers using Zai pits had large herds of livestock, bigger families and more transport facilities, which are consistent with their need for workforce and organic manure (Slingerland & Stork, 2000). Wildemeersch *et al*. (2015) identified that lack of enough knowledge on erosion and other vital resources such as manure, agricultural equipment and transport facilities limit the adoption of Zai in Tillaberi, Niger. In northern Burkina Faso, Sidibe (2005) found that variables such as education and perceptions of soil degradation were determinants for the adoption of Zai technique. A study by Ndah *et al*. (2014) showed that positive institutional factors such as a well-structured extension system contributed to the high adoption of Zai pits in Malawi and Zambia (Nyanga, 2012). Besides, the integration of farmer to farmer extension approach has been of significance in the adoption of Zai pit technology (Haggblade & Tembo, 2003). These studies focus on demographic characteristics of farmers and resource availability to explain adoption problems in different regions. However, research related to factors influencing farmers' adoption of Zai pits in Kenya is scanty.

Therefore it is not sufficient to infer these results for sub-humid and drier regions of Kenya. Moreover, Zai pits have their unique characteristics and requirements different from other rainwater harvesting technologies; hence, it is essential to establish factors that influence its adoption. The results of this study will provide entry points for planning or adjusting some of the current and future promotion efforts of Zai pits as a technology intended to reduce the total loss of production experienced in semi-arid areas. Improving the efficiency of rainwater use is, therefore, pertinent, especially in Kenya, where rainfed agriculture dominates.

2 Materials and methods

2.1 Study area

The study was carried out in Tharaka South sub-county, Tharaka-Nithi County, located in Eastern Kenya (Figure 1). It has an area of 1,569.5 km^2 and a population of 175,905 people (KNBS, 2010). The agro-ecological zone of the study area is the inner lowland zone (IL5). It has a bimodal rainfall distribution, namely a short rains (SR) and a long rains (LR) season. Annual rainfall in the agro-ecological zone (AEZ) IL5 is 500–750 mm with a mean annual temperature of 24°C (Smucker & Wisner, 2008). IL5 has a very uncertain first cropping season, and the second season is very

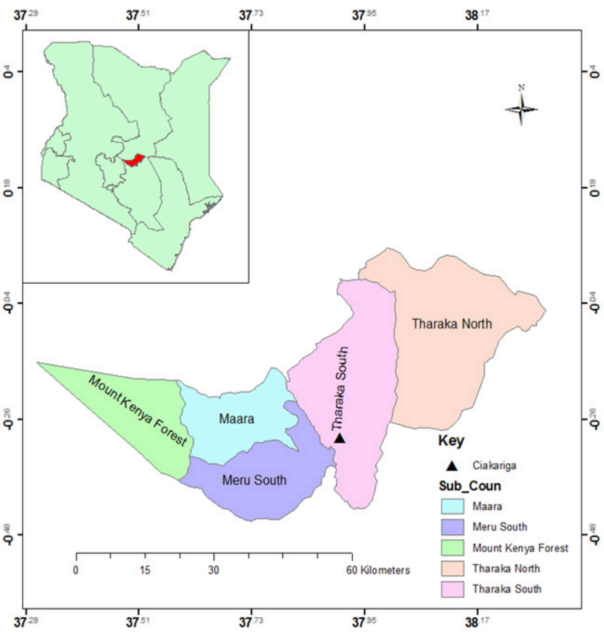

Fig. 1: *Map of the study area Tharaka-Nithi County.*

short (Jaetzold *et al.*, 2006). Rainfed agriculture is not economical without the use of runoff-catching techniques. Despite bimodal distribution, it is mostly inadequate to meet requirements for crops and fodder. The predominant soils in the study area are ferrasols that are highly weathered and leached (Jaetzold *et al.*, 2006). The primary source of livelihood for the Tharaka people revolves around marginal farming and livestock rearing (Nderi *et al.*, 2014) which are much affected by long spells of drought, which at times lead to total crop failure and massive loss of livestock.

Due to dependence on unreliable and unpredictable means of livelihood, poverty is widespread standing at about 65 % (Jaetzold *et al.*, 2006; Kristjanson *et al.*, 2010). Consequently, the overall development of the district has been negatively affected, as most of the emigrants are active labour force. The distribution of relief food and school-feeding programmes are some of the indicators of the extent of poverty.

2.2 Collection of data

Tharaka-Nithi county is sub-divided into Tharaka North, Maara, Meru South (currently known as Chuka) and Tharaka South sub-counties. Tharaka South sub-county was purposively selected from a list of the four sub-counties in Tharaka-Nithi county as NGOs and the Ministry of Agriculture have here promoted water and soil conservation technologies. The list of the households from the chiefs of the locations made the sampling frame. Exponential discriminative snowball sampling approach was used to identify farmers who had adopted Zai technology in six locations of Tharaka South sub-county. The approach was used to ensure uniform spatial distribution of the subjects over the entire sub-county. The measure of adoption was the actual presence or use of the technology in farmers' fields. For the non adopters, random sampling technique was applied at 8 % confidence interval and 95 % confidence level (Cochran, 1963), resulting in a sample size of 151. The distibution of households per location and sample sizes are shown in Table 1.

Table 1: *Distribution of household and sample size in the study area by administrative units.*

Location	*HH*	*Adopters*	*Non Adopt.*	*Sample*
Chiakariga	1,324	18	35	53
Gakurungu	1,331	20	34	54
Kamanyaki	572	10	13	23
Kamarandi	788	15	17	32
Nkarini	1,145	27	19	46
Tunyai	2,068	50	33	83
Total	7,228	140	151	291

HH: Households; Non Adopt.: Non Adopters

To facilitate the process, seven enumerators who had attained tertiary education level were recruited and trained prior to pre-testing. Pre-testing of the questionnaires was done to ascertain the validity of questions before the actual survey, to evaluate the performance of the enumerators, and to ensure uniformity. Necessary adjustments were made accordingly to improve the questionnaires after the pre-testing exercise. A structured interview schedule was administered to all selected household heads to gather information on household demographic characteristics, water harvesting techniques and soil fertility-related issues. Before data entry, all the completed interview forms were examined thoroughly to determine farmers who had adopted the Zai pit system (adopters) and those who had not (non-adopters).

2.3 Data analysis

Data were analysed using statistical package for social sciences (SPSS version 20) using descriptive and inferential statistics. The description was made using frequency, mean, and percentage. To determine factors influencing Zai pits adoption, binary logistic regression was used in Zai pit adoption model. According to the diffusion of innovation theoretical perspective, a farmer's response towards innovation is binary, either adopts or rejects. Hence the model for Zai adoption was as shown in equation 1.

$$\text{Log (P/1-P)} = a + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots. + \beta_8 x_8 + \varepsilon \quad (1)$$

Where
P is the probability of adopting Zai pits
(1-P) is the probability that a farmer does not adopt Zai pit
a = y-intercept
β = regression coefficients
ε = error term
$x_1 - x_{11}$ = independent variables (. . . . .)
Independent variables were the socio-economic characteristics as follows:

x_1 Non-formal trainings (continuous)
x_2 Household size (continuous)
x_3 No groups (continuous)
x_4 Land Slopy (0 = no, 1 = yes)
x_5 Formal title deed (0 = no, 1 = yes)
x_6 Soil fertility status (1 = high, 2 = moderate, 3 = poor)
x_7 HH wealth status (1 = rich, 2 = average, 3 = poor)
x_8 Received relief (0 = no, 1 = yes)
x_9 Sell farm produce (0 = no, 1 = yes)
x_{10} Improved planting material (0 = no, 1 = yes)
x_{11} Total farm size (continuous)

3 Results

3.1 *Social demographic characteristics of adopters and non-adopters of Zai pit technology*

The respondents interviewed composed of 77 % male farmers and 23 % female farmers (Table 2). About 52 % of the respondents were non-adopters, while 48 % were adopters. The observation made in this study is that amongst the adopters, the percentage of female farmers is lower than amongst the non-adopters. A higher percentage of middle-aged farmers (41–60 years) had adopted Zai pits compared to older farmers (61–80 years) and young farmers (21–40 years) (Table 2). In addition, middle aged farmers were more among the adopters as compared to the non-adopters. Most of the farmers (64 %) had at least primary education. Among those with no formal education, majority were non-adopters. Majority of farmers (85 %) depended on farming activities for survival and generation of income. Amongst the employed respondents, only 33 % were adopters.

Table 2: *Social demographic characteristics of adopters and non-adopters of Zai pit technology in Tharaka-Nithi County*

	Non-adopters % (n = 140)	*Adopters % (n = 151)*	*Total % (n = 291)*
Gender			
Male	72	81	77
Female	28	19	23
Age (years)			
21–40	48	34	41
41–60	35	52	43
61–80	17	14	16
Level of education			
No formal education	22	13	18
Primary education	61	67	64
Secondary education	9	11	10
Tertiary education	8	9	8
Main occupation of the household head			
Farming	83	88	85
Business	5	6	6
Employed	12	6	9

3.2 *Integration of Zai pits and soil fertility amendments*

Ninety-five percent of the farmers who had adopted Zai pits used animal manure as a soil fertility amendment (Table 3). Only 2.1 % of the farmers combined animal manure plus mineral fertiliser as input. At least 17.1 % of the farmers utilised Zai pits in combination with green manure while only 4.3 % applied mineral fertiliser only in the Zai pits. Further, 6.4 % reported having not used any input at all on Zai pits (Table 3). A combination of animal manure and crop residue had also been applied by 27.9 % (Table 3). Farmers in the study area also reported using different sources of manure and applied different amounts of manure ranging from 0.05 kg to 3 kg per Zai pit.

Table 3: *Combination of Zai pits and soil fertility improvements in Tharaka-Nithi County*

Zai pits + integrated soil fertility management	*HH %* (n = 140)*
+ animal manure	95.0
+ green manure	17.1
+ mineral fertiliser	4.3
+ animal manure + mineral fertilisers	2.1
+ crop residues + mineral fertilisers	2.9
+ animal manure + crop residues	27.9
no amendment	6.4

*Households that applied this combination

3.3 *Benefits and challenges of Zai pits*

Farmers were requested to score the Zai benefits between 1 and 5 where 1 = least important, 5 = very important and score the Zai challenges between 1 and 5 where 1 = least challenging and 5 = most challenging. Farmers perceived Zai pits to have various benefits with high economic returns getting the highest rating. Control of soil erosion and improved soil fertility were also regarded as being significant with a mean score of 4.0 and 3.9, respectively (Table 4). Fewer weeds, as well as low input application, were not considered as significant benefits in the adoption of Zai pits. The biggest challenge perceived by the farmers was that Zai pits are both labour intensive and highly demanding, particularly during construction. The fact that a farmer cannot use animal traction was equally considered as a significant challenge. However, the absence of immediate benefits was not perceived as a significant challenge by most of the farmers.

Table 4: *Benefits and challenges of Zai pits in Tharaka-Nithi County (1–5 scale; n = 140)*

	Mean scores	*Std. Deviation*
Benefits of Zai pits		
High economic return	4.7	0.77
Improve soil fertility	3.9	0.87
Less weeds	2.2	0.97
Precise application of inputs	2.4	1.01
Control soil erosion	4.0	1.02
Increased water retention	3.7	1.06
Ease application pesticide	2.8	1.13
Challenges of Zai pits		
Labour intensive	4.1	1.25
Difficult to maintain	3.9	1.14
Requires skills	3.2	1.02
Occupy large portion land	3.1	1.33
No immediate benefits	2.1	1.05
Not possible to use animal traction	3.7	1.46
Waterlogging	2.8	1.42

3.4 Predictors of Zai system adoption by farmers

A logistic regression analysis was conducted to predict adoption of Zai system for 291 households using non-formal training, household size, membership in social groups, land inclination, formal land title, soil fertility status, household wealth status, received relief, selling farm produce, improved planting material, and total farm size as predictors (Table 5). A test of the full model against a constant model was statistically significant, indicating that the predictors, as a set, reliably distinguished between adopters and non-adopters of Zai system (chi-square 90.107, $p<0.001$, df=13). Overall prediction success was 75.3 % (74.4 % for non-adopters and 76.2 % for adopters) (Table 5). The Wald criterion demonstrated that non-formal training, number of groups, soil fertility status, household wealth status, received relief and sell of farm produce made a significant contribution to prediction (Table 5).

Household size, land inclination, soil fertility status, use of improved planting material and total farm size had no significant influence on the adoption rate of Zai system (Table 5). Non-formal training significantly and positively influenced the adoption of the Zai system. The exp (β) value associated with non-formal training attended by the household head was 2.81. The number of social groups a household head belonged to had a positive effect on the adoption of Zai system. The exp (β) shows that for a 1-unit increase in the number of groups, the probability of adoption would increase by a factor of 1.62. The results also indicated that there was a statistically significant relationship between soil fertility condition of the land and the adoption of Zai pits at p=0.05. Wealth status of the household head had a positive effect on the adoption of Zai system. Farmers ranked as poor were more likely to adopt the Zai system as compared to those who were wealthy. The exp (β) value associated with wealth status was 4.17. Hence, with one unit increase of wealth status, the odds for adoption would decrease by 4.16. Received relief significantly (p=0.01) and positively influenced the adoption of Zai system by farmers. The exp (β) showed that the odds of a farmer receiving relief food were 4.63 times likely to adopted compared to those who were not. Household heads who sell farm produce had a significant (p=0.05) and positive impact on the adoption of Zai system. The exp (β) value associated with the sale of farm produce as a factor that influence adoption of Zai system was 7.75 at p=0.05.

4 Discussion

The gender difference is known to determine the choice of soil conservation and water harvesting technique (Asfaw & Neka, 2017; Theriault *et al.*, 2017). Women base their choices on the opportunity cost of realising better yields while men consider cost-related matters such as labour and time requirements (Kamau *et al.*, 2014; Ndiritu *et al.*, 2014). Due to the commitment of women in non-farm activities such as looking after the children and fetching water and firewood, they are likely to be attracted to less labour intensive technologies other than Zai pit technology (Wodon & Blackden, 2006). Demographic characteristics of this study show that the percentage of women in the non-adopters group was far much higher than in the adopters group. Previous research by Mudhara *et al.* (2002) also found that female

Table 5: *Predictors of Zai system adoption by farmers*

Variables	*B*	*S.E.*	*Wald*	*Df*	*Sig.*	*Exp(β)*
Non-formal training (continuous)	1.04	0.27	15.08	1	0.001	2.81
Household size (continuous)	0.15	0.08	3.55	1	0.059	1.16
Membership in social groups (continuous)	0.49	0.16	9.53	1	0.002	1.62
Land sloppy (0 = no, 1 = yes)	0.49	0.34	2.12	1	0.145	1.64
Formal land title deed (0 = no, 1 = yes)	-0.42	0.34	1.51	1	0.221	0.66
Soil fertility status(1 = high, 2 = moderate, 3 = poor)	1.08	0.46	5.45	1	0.02	2.95
HH wealth status (1 = rich, 2 = average, 3 = poor)	1.43	0.57	6.23	1	0.013	4.17
HH received relief (0 = no, 1 = yes)	1.53	0.37	16.78	1	0.001	4.63
Sell farm produce (0 = no, 1 = yes)	2.05	0.84	5.97	1	0.015	7.75
Improved planting material (0 = no, 1 = yes)	0.64	0.36	3.07	1	0.08	1.89
Total farm size (continuous)	0.03	0.04	0.49	1	0.482	1.03
constant	-12.4	2.35	27.76	1	0	0

B – intercept; Wald - Wald chi-square to test the null hypothesis that the constant equals 0; Df- degrees of freedom; Sig- significant; Exp(B) – exponentiation of the B coefficient, which is an odds ratio.

farmers are less likely to adopt technologies that are labour intensive.

Most of the middle-aged farmers had adopted Zai pits compared to older farmers and young farmers. This was attributed to the labour-intensive nature of the Zai pit technique (Nyamadzawo *et al.*, 2013). It may also be pointed out that middle-aged farmers may have good understanding and experience of their environment and the benefits of particular techniques compared to young farmers. According to a study by Theriault *et al.* (2017) and Mango *et al.* (2017), age of the farmer is a significant factor that can affect the use of soil conservation technologies. This is attributed to the fact that younger farmers may be less interested in food security matters while the middle-aged farmers could be more aware of the benefits of water harvesting technologies through experience. Besides, older farmers may be more conservative, less flexible and more uncertain about the benefits of Zai pits.

According to Mango *et al.* (2017), education levels of the farmers may have influenced the chances of implementing and adopting the water harvesting techniques. This study showed that most of the respondents with no formal education were non adopters. This is because education exposes one to information and therefore creates awareness and enhances the adoption of water harvesting systems. Chianu & Tsujii (2005) and Theriault *et al.* (2017) also reported that farmers' educational achievement could increase the probability of water harvesting technology adoption.

The study suggests a low use of soil fertility amendments except for animal manure in combination with Zai pits. This could be due to the availability of animal manure locally. According to Liniger *et al.* (2011), combining different soil fertility amendments with soil and water conservation is more suitable. Manure placed in the pits improves plant growth, and better use is made of the harvested water (Anschütz *et al.*, 2003). In Burkina Faso, a combination of manure application with Zai pits resulted in more than two-fold grain yield compared to that without manure (Fatondji *et al.*, 2006). Water and soil conservation techniques cannot succeed without nutrient application as poor nutrient status is, besides limited water availability, one of the paramount crop growth limiting factors (Wildemeersch *et al.*, 2013). For optimal yields, 3 t of manure ha^{-1} or 300 g per Zai pit should be applied (Fatondji *et al.*, 2006). Low application of inorganic fertilisers is also in line with studies by Morris *et al.* (2007) and Potter *et al.* (2010) who reported that majority of smallholder farmers use no (0 kg ha^{-1}) or low (8 kg ha^{-1}) rates of mineral fertiliser in Africa, compared with a mean 100 kg ha^{-1} application rate in Asia.

Implementation of Zai pits has been observed to be labour intensive by several studies (Etongo *et al.*, 2018, Schuler *et al.*, 2016, Lenhardt *et al.*, 2014). High labour demand lowers the adoption given that farmers may not have enough household labour available or not enough capital to hire labour. High economic returns could be associated with the increased yields that occur as a subsequence of water retained in the pit despite unreliable rainfall within the region. Zai pits also collect and concentrate water at the plant rooting zone. This reduces the risk of water stress in a region of low and erratic rainfall. Another advantage of using pits is that they enhance the capture of water from the onset of the rains and also enable the precise application of organic and inorganic fertilisers. Although fewer weeds scored the least in the benefits of Zai pits, it is usually an advantage since nutrients and moisture are concentrated in the hole and thus weeds are disadvantaged (Kaboré & Reij, 2004). However, it is not possible to use animal traction on the digging of Zai pit, and hence, this makes it a challenge for large-scale farmers (Fatondji *et al.*, 2009).

The results of logistic regression analysis suggests that the more non-formal training a farmer attends on farming techniques, the more likely they are to adopt the Zai system. Lukuyu *et al.* (2012) observed that non-formal training is a cost-effective way of disseminating information even after phasing out agricultural related projects. These results are consistent with Rogers (2003) innovation diffusion theory, which postulated that information access is central to the process of innovation adoption. In most adoptions, extension services provided through formal and informal institutions are a vital factor in making farmers aware of and enabling them to promote new agricultural technologies (Thapa & Rattanasuteerakul, 2011; Paudel & Thapa, 2004). Farmers who were members of different social groups were more inclined to adopt Zai system than those who were not. Farmer groups predispose farmers to increased learning opportunities for improved water harvesting technologies and exchange of information among themselves on the advantages of Zai ignites them to apply the technology on their farms. Studies have also shown a positive relationship between the adoption of conservation practices and membership in farmer organisations (Nyanga, 2012). The increased likelihood to adopt Zai pits when farmers belonged to a group, could suggest that the groups were sources of information on water and soil conservation. (Muchai *et al.*, 2014).

Farmers who perceived their farmland to be low in fertility were more likely to adopt the Zai system than those who perceived their soil fertility as high. This is consistent with research findings by Tadesse & Belay (2004) who reported that farmers who feel that their farmlands are prone to soil erosion are more likely to adopt physical soil conservation measures than those who do not perceive the problem of soil erosion. Another observation made in this study was that poor farmers were more likely to adopt Zai pit as a water harvesting technology. It implies that 'wealthier' farmers may not invest more in Zai pits, probably because they are manually dug while they may have a greater ability to hire tractors or other mechanised power to prepare their lands.

Possession of formal title deed had an insignificant negative impact on the adoption of Zai system. However, it is usually expected that farmers who have title deeds are more likely to adopt Zai pits as compared to those who do not. Zai pits are inherently a long-term investment requiring the security of tenure over land for an extended period. Many smallholder farmers who apply these technologies on leased land can lose the benefit of their investments as the owners can withdraw the land for their use. Tenure insecurity explains farmers' unwillingness to invest effort in measures to improve soil conservation and enhance fertility (Lovo, 2016).

According to the logistic model land size, family size, the sloppiness of land and use of improved planting material were not significant variables in the adoption of Zai pits. The findings differ with those of Huenchuleo *et al.* (2012) who established farm size to be among the significant predictors in the adoption of soil and water conservation measures in Chile. These results also contradict the findings of Tadesse & Belay (2004) and Amsalu & de Graaff (2007) who identified the significant positive influence of land size on farmers' decision to adopt soil conservation measures. In the highlands of Eritrea, a study by Araya & Asafu-Adjaye (2001) indicated that family size was a significant variable affecting soil conservation efforts. The findings were in agreement with the study of Mango *et al.* (2017), who found that family size had a positive significance in the adoption of soil conservation measures. This is because larger households will be able to provide the required labour force for the implementation of soil-conserving structures as constructing soil-conserving structures is labour intensive. Anley *et al.* (2007) indicate that farmers were inclined to invest in conservation practices where their farm plots are located on higher slopes. Similar results on the effect of plot slope were reported by Amsalu & De Graaff (2007) in Ethiopia. This is attributed to the fact that most conservation practices are mainly used to control soil erosion in hilly areas, and the benefits are also expected to be higher in these areas.

5 Conclusion

The findings indicate that the number of non-formal trainings, beneficiaries of NGOs, wealth status and membership in social groups play an essential role in the adoption of Zai pits. It was also observed that very few farmers apply inorganic fertiliser on Zai pits. Farmers perceived the high economic returns of the pit to be the most significant benefit, while intensive labour was deemed the most limiting in its utilisation. In regards to these findings, farmers should be encouraged to join groups or associations and attend non-formal training on agricultural practices. Also, farmers should be encouraged to use other soil fertility amendments such as compost, organic fertilisers and green manure in addition to animal manure in combination with Zai pits for favourable outcomes. The paper recommends that both government and non-governmental organisations should invest significant resources in training and creating awareness on the benefits of Zai pits. Based on the findings, there is a need for agricultural policymakers to develop and implement appropriate agricultural guidelines for extension service providers and smallholder farmers on the effectiveness and efficiency of the Zai pits. This will enable smallholder farmers to make informed decisions on adoption of the technology as a coping mechanism to climate change, enhancement of food security and alleviation of poverty in the semi-arid tropics in sub-Saharan Africa.

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Conflict of interest

The authors declared no conflicts of interest with respect to the research, authorship, and publication of this article.

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